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WATER RESOURCES ACTIVITIES IN THE UNITED STATES FLOOD PROBLEMS AND MANAGEMENT IN THE TENNESSEE RIVER BASIN

Select Committee on National Water Resources, U. S. Senate

December 1959

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COMMITTEE PRINT NO. 16

WATER RESOURCES ACTIVITIES
IN THE
UNITED STATES

FLOOD PROBLEMS AND MANAGEMENT IN THE TENNESSEE RIVER BASIN

SELECT COMMITTEE ON NATIONAL WATER RESOURCES
UNITED STATES SENATE

PURSUANT TO

S. Res. 48

EIGHTY-SIXTH CONGRESS
FIRST SESSION

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(Pursuant to S. Res. 48, 86th Cong.)

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STATEMENT BY THE CHAIRMAN

DECEMBER 18, 1959.

To the Members of the Senate Select Committee on National Water Resources:

Among the problems with which the Select Committee on National Water Resources is concerned in its studies pursuant to the provisions of Senate Resolution 48 are those relating to ways and means by which life and property can be protected from the ravages of floods. For years, Federal, State, and local agencies have made efforts to cope with the flood problem; however, each year brings its history of excessive damage and loss of life.

Federal programs for flood prevention and control have been carried out by several agencies. Programs for runoff and waterflow retardation and soil erosion prevention, the so-called small watershed program, have been carried on by the Department of Agriculture. Downstream flood control works are the responsibility of the Corps of Engineers. Flood control works in connection with the reclamation of the West have been accomplished by the Bureau of Reclamation. Other Federal agencies have peripheral responsibilities in the field of flood control.

In the Tennessee River Basin, the Tennessee Valley Authority has its responsibility for flood prevention and control measures of all kinds as a part of its integrated resource development program which covers an area of about 40,000 square miles, including rugged mountain terrain, broad valleys, and rolling hills. Annual rainfall within the Tennessee River Basin ranges from over 90 inches to less than 40 inches. In its 25-year history, TVA has made great progress toward achieving flood control in the area in which it has responsibility. In order that the committee might have the benefit of the experience gained by the Tennessee Valley Authority in this field, I requested the Authority to prepare a report for us based on its experience in the field of flood control, and to make whatever suggestions were believed to be appropriate as to how the experience gained in the Tennessee Valley might be applied to solution of flood problems in the Nation as a whole.

Other reports are being prepared for the committee by the Corps of Engineers of the Department of the Army, and by the Department of Agriculture, dealing with the aspects of the flood control problems which are included among the responsibilities of those Departments. In addition, a discussion of the program of the Weather Bureau of the Department of Commerce for alleviation of flood damages through forecasting is included in Committee Print No. 25.

The report prepared by the Tennessee Valley Authority in response to my request should be of great interest to you, to other Members of the Senate, and to all others concerned with finding solutions to the Nation's water resource problems. Accordingly, I am having the report printed as one of our committee prints dealing with all aspects of water resource activities which are being considered by the committee.

ROB'T S. KERR,
Chairman, Select Committee
on National Water Resources.

COMMUNICATIONS

AUGUST 25, 1959.

Hon. HERBERT D. VOGEL,
Chairman of the Board of Directors,
Tennessee Valley Authority, Knoxville, Tenn.

MY DEAR MR. CHAIRMAN: A copy of Senate Resolution 48, adopted April 20, 1959, under authority of which the Select Committee on National Water Resources was formed, is enclosed for your information. The committee is charged with the responsibility for making studies of the Nation's water resources problems to form a basis for recommendations to the Senate on water resource policies for the future.

Under the provisions of the resolution the committee is directed to make full use of studies and plans prepared by executive agencies and the agencies are requested to give such assistance as may be required. In view of the broad experience of the Tennessee Valley Authority in dealing with all aspects of flood management in the Tennessee River Basin it is believed that your agency can be helpful to the committee in its consideration of this aspect of water resource development. Accordingly, it is requested that a report be prepared for the committee based on TVA's experience in the field of flood management and control, with whatever suggestions you would like to make as to how the experience gained in the Tennessee Valley might be applied to the solution of flood problems in the Nation as a whole.

We would like the report to give a general discussion of flood problems of the Tennessee River Basin, and how they are handled. In particular we would like to have discussion of alternative means of reducing or preventing flood damages by means of reservoirs, levees, channel improvements, and other downstream protective works; improved land use practices and upstream flood preventive measures; controlling the use and occupancy of flood plains; and improved systems of flood forecasting in conjunction with the other methods. Insofar as practicable specific examples should be discussed, in terms of costs, benefits, and relationship to water resource development for other purposes. In view of the experience of your agency in dealing with all of these means of flood management we would like to have the report conclude with any suggestions which you would like to make as to future Federal activity in this field as related to overall water resource development problems.

We would like this information to be made available, if possible, in a summary report of not more than 10,000 words with whatever tables, charts, appendixes, and graphic illustrations as may be considered necessary. It would be most helpful if this report could be furnished the committee by November 1, 1959.

Should any problems arise in connection with the preparation of this report, Mr. Theodore M. Schad, staff director for the committee, will be glad to discuss them with representatives of your agency.

Sincerely yours,

ROB'T S. KERR, *Chairman.*

TENNESSEE VALLEY AUTHORITY,
OFFICE OF THE BOARD OF DIRECTORS,
Knoxville, Tenn., November 18, 1959.

Hon. ROBERT S. KERR,
Chairman, Senate Select Committee on National Water Resources,
Washington, D.C.

DEAR SENATOR KERR: The accompanying report entitled "Flood Problems and Management in the Tennessee River Basin" was prepared in response to your letter dated August 25, 1959, requesting that TVA report on its experience in the field of flood management and control with appropriate suggestions as to how TVA's experience might be applied to the solution of flood problems in the Nation as a whole.

In compliance with your request, the report summarizes the variety of flood problems in the Tennessee River Basin. Following this is a general discussion of the various methods of reducing or preventing flood damage, including engineering works such as reservoirs, levees, and channel improvements, changing the use of flood plain land through zoning regulations, and watershed protection through improved land use. The report then describes the system of flood storage reservoirs that was built to reduce floods at Chattanooga, Tenn., and to contribute flood relief to other Tennessee Valley cities and to the lower Ohio and Mississippi Rivers. The economic justification for the flood control system is given and also a summary of the accomplishments to date.

Since the reservoir system does not provide full protection to many communities nor any protection to upstream communities on small tributaries, and since it would not be economically feasible to provide protection in most cases, TVA initiated a program to provide communities with flood information and to encourage them to adopt zoning regulations to control the use and occupancy of flood plains. By such regulations, potential flood damage would not be permitted to increase and over a long period of time would decrease. A description of the extent of this program and its accomplishments to date is included in this report. The program is also covered in greater detail in a report entitled "A Program for Reducing the National Flood Damage Potential" submitted to the Congress in March 1959, which was printed in August 1959 by the Senate Committee on Public Works.

The report concludes with suggestions for future Federal activity in the field of flood damage prevention based on TVA's experience over the past 25 years.

Sincerely,

HERBERT D. VOGEL, *Chairman.*

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FLOOD PROBLEMS AND MANAGEMENT IN THE TENNESSEE RIVER BASIN

Introduction

In the following report, TVA summarizes its experience in the regulation of floods through its basinwide, multiple-purpose system of dams and reservoirs, and its experience in the regulation of developments in the flood hazard areas. It wishes to make clear, however, that because the report deals with flood damage prevention only, it cannot sketch in full perspective the social and economic values which result from river regulation as it exists in the Tennessee Valley.

TVA's mandate from Congress was to view all objectives in its integrated resource development program. From its experience, TVA believes that the unified approach is more valid today than ever before and that any approach to flood control on any other river system should examine carefully the broadest base of resource use. Congress directed TVA to construct dams and reservoirs to control destructive floodwaters in the Tennessee and Mississippi River drainage basins. From its experience, the following specific findings were made with respect to flood control.

1. TVA found that a system of high dams and reservoirs was necessary to store the large amounts of floodwater. The flood regulation afforded by these reservoirs protects life and property; makes the shoreline many times safer and more usable for industrial sites, home sites, and recreation development; and conserves water for the increased demands of modern society.

2. The average annual flood control benefits of this system were found to be nearly double the average annual costs, the benefit-cost ratio being 1.96:1. During the period of about 23 years that this system has been in operation, the accumulated benefits, including only the damages averted at Chattanooga and in the lower Ohio-Mississippi River Valleys and the benefits of increased land values to the Ohio-Mississippi region by virtue of greater security from floods, have been more than sufficient to amortize the entire flood control investment plus all accumulated annual expenditures.

3. As part of the unified approach to the valley development, agricultural and forestry programs were initiated which have provided improvements to farming systems that conserve land and water resources. These improvements, even if carried out over a large part of the watershed, were found to be valuable and desirable but were not considered to be significant in reducing major floods.

4. The system of dams and reservoirs reduces the depth and frequency of flooding at many areas, but flood problems remain, particularly on tributary streams. It has been found that it would be feasible to correct some of these remaining problems by means of protective works, but in many cases no feasible plan can be devised.

5. To stem the growing flood damage potential where complete protection has not been provided or where protective works are not economical, TVA has encouraged controls over developments. It believes that the avoidance of flood damage by such controls is possible and practical and goes hand in hand with flood regulation by engineering works.

The Flood Problem in the Tennessee Valley

Description of Valley

The watershed of the Tennessee River covers an area of 41,000 square miles. The terrain varies from rugged mountains along the eastern rim to broad valleys and the rolling country of the western areas. Principal tributary streams fall from the Blue Ridge Mountains and from the Cumberland Plateau. The main stem of the Tennessee River curves crescent-shaped from Knoxville, Tenn., southwestward and then to the northwest to the Ohio River, a distance of 650 miles. In this

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course, it falls 500 feet. The high, eastern valley rim reaches elevations more than 6,000 feet above mean sea level. At the mouth of the Tennessee River, the flood plain is generally slightly above elevation 300.

PRECIPITATION AND RUNOFF

This is a region of generous rainfall, averaging 52 inches annually for the valley as a whole. Locations in the mountainous southeastern section show annual averages in excess of 90 inches. Some locations at the other extreme average less than 40 inches. The greatest total recorded in any calendar year was 133.3 inches in 1957 at Haywood Gap, N.C. Annual totals for the valley range from 38 inches in 1941 to near 65 inches in 1957.

In general, seasonal variations in rainfall are not pronounced. The months of August, September, and October are typically on the dry side. For most of the valley, the winter months produce the largest amounts, but in some eastern areas July rainfall is greatest.

Streamflow records, however, show a strong seasonal pattern in which the high flows of the winter and early spring months stand out clearly. Flows decline generally during summer and fall months and recover usually in December.

FLOOD PROBLEMS

Occurrence of great valleywide floods would, of course, be expected to fit the seasonal runoff pattern. This is illustrated by the flood history chart for Chattanooga (fig. 1). At the top of the chart, flood heights are plotted by years, beginning with 1867 on the left and progressing to the present day on the right. It shows the extreme irregularity with which large floods occur. The largest occurred in 1867 and the second largest in 1957. The lower plotting shows the distribution of the same floods by months of the year. It shows that all of the large floods occurred during the period from late December to early April, following the seasonal runoff pattern.

Great floods in smaller areas have occurred in all seasons of the year. Examples of floods that have occurred over substantial segments of the valley are those of May 1901, July 1916, March 1929, August 1940, February 1948, and March 1955. Many small communities have been affected by extreme local area floods in all seasons. These maximum known floods are of considerable importance, but studies of meteorology and hydrology reveal that all of them probably will be exceeded in the future.

Prior to TVA, more than 754,000 acres of land had been flooded by the maximum known floods in the regions of the valley now lying in or downstream from TVA reservoirs. Somewhat lesser areas have been flooded periodically, damaging urban communities, crops and livestock, roads, railroads, communication facilities, and drainage structures.

The cities in the valley most seriously affected by floods were Elizabethton, Tenn., on the Watauga River; Kingsport, Tenn., on the South Fork Holston River; Asheville and Marshall, N.C., on the French Broad River; Canton, N.C., on the Pigeon River; Harriman, Tenn., on the Emory River; and Knoxville, Dayton, and Chattanooga, Tenn., on the Tennessee River. Because of the growth of some communities since TVA was established, new serious flood problems have appeared, as at Gatlinburg, Tenn., a resort city on a swift mountain stream.

Since the Tennessee River is often a major contributor to Ohio and Mississippi River floods, the reduction of floods at Cairo, Ill., at the junction of the Ohio and Mississippi Rivers is a major objective of flood control in the Tennessee Valley. Reductions effective at that point are also effective for a considerable distance downstream along the Mississippi River. Flood crest reduction is equivalent to increasing the height of hundreds of miles of downstream levees guarding 6 million acres of productive land. Moreover, some 4 million acres not protected by the levee system would have the depth of flooding reduced by reservoir regulation.

The greatest urban flood damage has been in Chattanooga, Tenn., one of the several valley communities which is only partly protected from floods by TVA reservoirs and where further protection of a local nature is needed. The highest four Chattanooga floods, excluding the 1957 flood, in a period of nearly 100 years occurred before the city achieved its present population and development. Figure 2 shows the area of Chattanooga that was flooded during the 1867 flood. The following table shows damages at Chattanooga which would have been caused by a repetition of these four floods, assuming no upstream regulation and the state of development and money values of 1953.

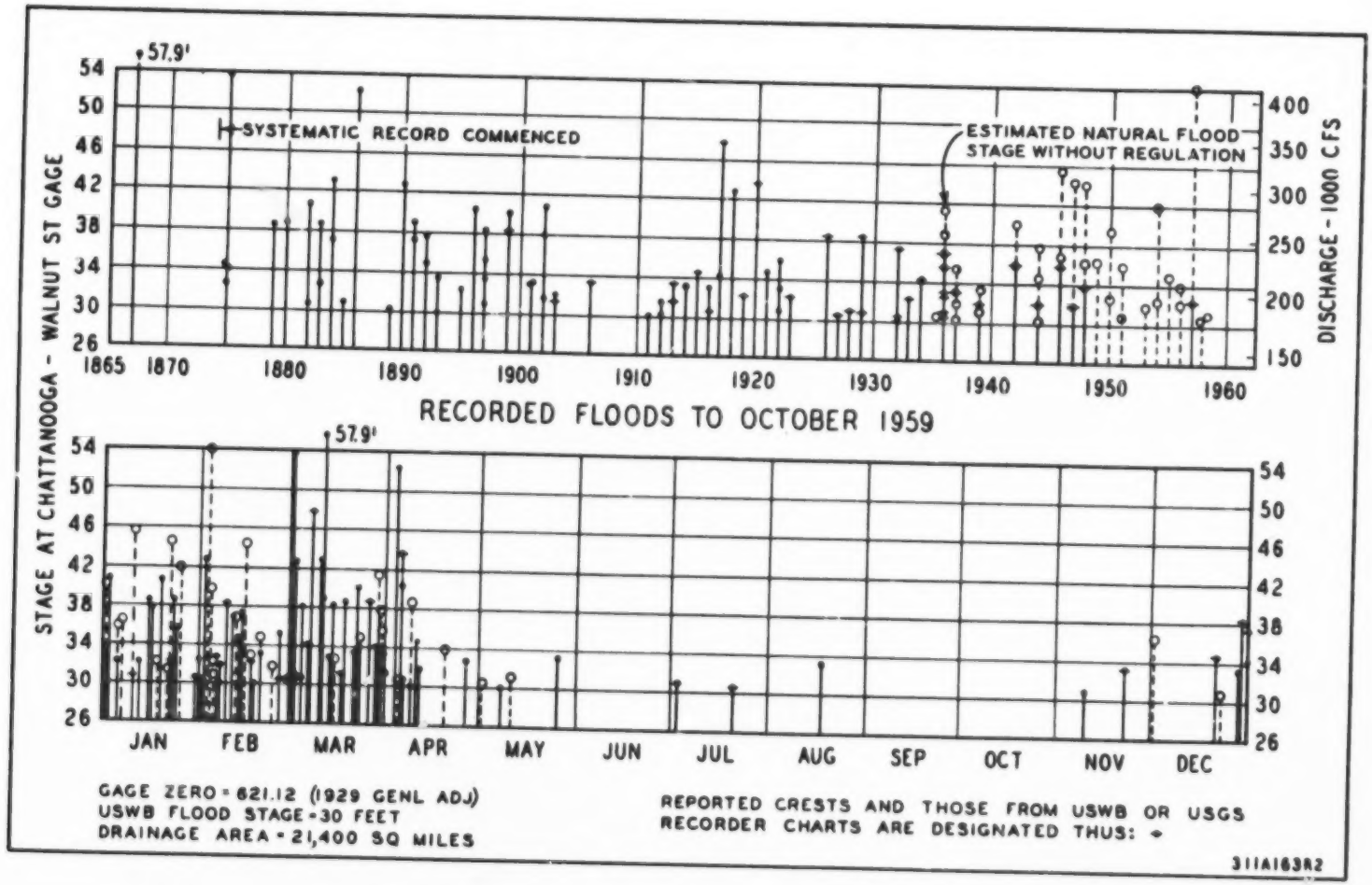

FIG. 1. DISTRIBUTION OF FLOODS AT CHATTANOOGA, TENN.

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FIG. 2. AREA FLOODED
1867 FLOOD
CHATTANOOGA AND VICINITY

Great Chattanooga floods prior to TVA

Date	Stage	Population—percent of 1939 population	Hypothetical damage
March 1867	57.9	4	$105,000,000
March 1875	53.8	7	64,500,000
April 1886	52.2	17	52,000,000
March 1917	47.7	41	25,500,000

According to a survey made in 1938, if there were no flood protection, a flood equal to that of 1867 would flood 12,630 Chattanooga homes, many of them on land 25 feet below the flood crest level. The entire commercial district would be flooded from 6 to 12 feet above street levels, involving more than 2,000 businesses. Almost all of the 250 industrial plants would be flooded. Ten years after the 1938 survey, the homes which would be flooded had increased to 14,390, and other types of property subject to flooding also had increased in number. To some extent, the potential damage has been aggravated by a movement toward locations at elevations even lower than those damaged or threatened by floods.

Agricultural lands have been both benefited and damaged by floods. Floods which have occurred out of the growing season have generally left a beneficial deposit over the flood plains. Major floods on the Tennessee River have not occurred in the growing season, but floods on some of the tributaries have occurred at a time to damage growing crops. For example, the floods of July 1916, August 1928, and August 1940 over the upper French Broad Basin all caused large damage to the rich farmlands above Asheville. In 1949 a series of moderate floods in June, July, and August in this basin caused damage, principally to truck crops, of more than a million dollars.

Railroads and highways have suffered particularly from floods. During the flood of July 1916, the Southern Railway was largely destroyed for a distance of 60 miles below Asheville, N.C. The flood of March 1929 on the Emory River caused great damage to the Southern Railway line between Cincinnati and Chattanooga and to other railroads within the Emory River Valley.

Alternative Methods of Preventing Flood Damage

Property may be protected from floods by some form of physical construction, such as levees and walls, channel improvements, and reservoirs. With this type of protection, no change is made in the property itself or its location. A second type of flood damage prevention is the protection of property on an individual, separate basis, such as the relocation or floodproofing of structures. Flood-warning systems to give time for removal of damageable property would fall in this category. A third type is to control the use and occupancy of the flood plain. A fourth type is the development and conduct of educational and action programs for securing land cover that is consistent with the objectives of water control, watershed protection, and optimum farm income.

Any one of the methods, or any combination of them, may prove to be the most economical in a given situation. Dividing the needed protection between two or more methods may prove cheaper than protection by a single method. For example, in reservoirs, both the volume of water to be stored and the cost of its storage space usually increase rapidly for each additional unit of downstream flood-stage reduction. Likewise, the cost of levees and rights-of-way in urban areas also increases rapidly with height, so that it may prove cheapest to provide partial flood reduction by a moderate amount of storage and to confine the flood so reduced between levees of moderate height. Partial reservoir protection may also be combined with zoning or removal below the protected zone.

Following is a brief discussion of the several methods of flood damage prevention and of their applicability in the Tennessee Valley.

Reservoirs

The use of reservoirs for storing floodwater to reduce downstream flood elevations has increased greatly in the past 40 years. Their practicability depends largely on the availability of feasible upstream dam and reservoir sites of sufficient capacity to control a substantial part of the area. Such reservoirs substitute deep, controlled flooding on land reserved for that purpose for uncontrolled flooding of valuable downstream property. Flood control reservoirs may be classified as to whether the discharge outlets are controlled by gates or have no gate control. The latter type, called

detention basins, discharges at almost a uniform rate during a flood. This rate of discharge is determined in advance and usually is about equal to the channel capacity downstream. The amount of storage space to be provided in any reservoir depends on several factors, but mostly on the size of the flood against which protection is to be given, the capacity of the channel at the flood-damaging stage, and the relative area controlled above the point of hazard. Generally a storage equivalent to between 6 and 12 inches of water over the drainage area is sufficient for controlling most floods in the Tennessee River Basin.

The congressional directive was that TVA construct dams and reservoirs of a type to produce the maximum benefit for navigation and at the same time to contribute to the control of destructive floodwaters in the Tennessee River and Mississippi River. This joint requirement of the act was fulfilled by using high dams and large reservoirs which would provide large amounts of floodwater storage. Small upstream detention reservoirs would not satisfy the requirement and have not been used in TVA's flood control program.

LEVEES

Levees or floodwalls are a positive means of holding floodwater off the land and have been used extensively. The confinement of the flow within a levee may raise the height of floods by elimination of valley storage and flow area; therefore, care must be taken to allow for this increased height in the construction of the levee. Levees introduce sanitary and storm drainage problems on the protected area, frequently requiring pumping systems. Roads, drains, and railroads passing through the levees must be provided with gates if the stream will be at high stage for long periods of time. Because of greater development behind a levee, structural failure or overtopping due to underdesign may result in damage greater than if there had been no levee.

Levees and floodwalls were found to be feasible and necessary for protection at Chattanooga in addition to the protection afforded by the multiple-purpose reservoirs. Plans of levees for the protection of Chattanooga to supplement the reservoir protection were prepared and Congress appropriated money to start construction. The project did not materialize, however, because the city did not meet Federal requirements for participation. Levees and channel improvements in conjunction with detention reservoirs also were found to be the most feasible means of protection at Asheville, N.C., and its adjacent agricultural land and at Bristol, Tenn.-Va. To date, however, levees and floodwalls have been utilized only in reservoir adjustment problems but have not been utilized in TVA's flood control program.

CHANNEL IMPROVEMENT

The purpose of channel improvement is to make a stream carry more water than formerly, thus reducing overflow and resulting flood damage for given flows. Channel improvements are often used in conjunction with levees and storage reservoirs. Lowering of the flow line by this method will tend to offset the raising caused by confinement by levees. The improvement in carrying capacity of the stream is accomplished by widening, deepening, realigning, or paving the channel. Often a considerable benefit may be obtained by cleaning the existing channel of bars, debris, and snags. In any channel improvement scheme, however, maintenance work will be required to continue the full effectiveness of the improved waterway area.

The magnitude of the flood problem, especially at Chattanooga and on the Mississippi River, precluded the application of such a method as the improvement of the channel of the Tennessee River. Channel improvement has not been employed in TVA's flood control program.

PROTECTING INDIVIDUAL PROPERTY

Protection of property on an individual basis may be accomplished by a wall or levee or by relocation to higher ground, either by elevating the existing site with fill or by removing to a new, higher location. Floodproofing of individual structures may be accomplished by providing for removable bulkheads for doors and windows, placing check valves on pipelines, sealing walls and floors against seepage, making necessary adjustments to electrical and other utility facili-

ties, and placing protective coatings on equipment A change in the use of the structure would also fall in this category.

The magnitude of the flood problem, as was the case with channel improvement and small upstream detention basins, precluded the application of individual property protection except in a few relatively insignificant cases.

FLOOD FORECASTING

From its beginning, TVA has maintained a flood-forecasting and river control organization. The valley is covered by a network of rainfall and streamflow stations from which reports are received daily or more often during flood periods. Some of these gages in remote locations operate through radio signals. Coupled with this system of reports are quantitative forecasts furnished by the U.S. Weather Bureau under a program that began more than 20 years ago. The river control engineers thus at all times have the best available forecasts of the quantities of rain that may fall over the various parts of the valley area. They also have continuous knowledge of the runoff in streams throughout the valley. This knowledge of hydrologic conditions throughout the valley, integrated with the control and operation of the TVA water projects, enables accurate forecasts of flows and stages.

In addition to the flood forecasting by TVA for locations affected by TVA projects, the U.S. Weather Bureau is providing flood-forecasting services for a number of communities located on uncontrolled streams. This latter service has reduced flood losses by enabling goods to be moved and property to be given emergency protection.

FLOOD PLAIN REGULATIONS

At new communities or at old communities that are expanding into new areas, controlling development through flood plain regulation is a useful tool in preventing the flood plain or overflow area from becoming occupied with damageable property. The laws or regulations necessary to control the development of such areas must be workable, fair, and practical or their enforcement will be impossible.

A more complete discussion of this method of flood damage prevention is given later under the heading "Controlling the Use and Occupancy of Flood Plains."

IMPROVED LAND USE

Along with the developments on the Tennessee River and its principal tributaries, TVA has been concerned with the improvement of the watershed itself. Congress directed that watershed improvement should proceed concurrently with the major river development. Under this directive, TVA has vigorously carried out programs over the watershed for improvement of agriculture and forestry.

With regard to the agricultural program, TVA has developed new and improved fertilizers which have been used, along with appropriate education on related farming practices, in a regional program of watershed protection and agricultural development. Demonstrations under practical farm conditions are conducted by the land-grant colleges, local farm groups, other Federal and State agencies, and selected fertilizer distributors and dealers. The improvements of farming systems that conserve land and water in the upper tributaries of the Tennessee River enhance the economic well-being of the farm families. The success in securing more desirable patterns of land use results from bringing the educational programs to the people to carry out at the local level. On agricultural lands subject to flooding, TVA, working through existing agencies, also tries to educate farmers on the advantages of changing to farming systems that would suffer the least economic loss when localized floods do occur. Such a program is comparable with that for encouraging controls on the use and occupancy in urban communities.

The forestry program has likewise given improved protection to the 14 million acres of forest land in the watershed. This has been in part through an increase in fire protection by the valley States from less than 50 percent to 95 percent of the forest area. As a result, there has been a reduction in the number of forest fires, an 80-percent reduction in the size of the average fire, and a 90-percent reduction in the annual average burn. Nearly 300,000 acres of eroded or otherwise unproductive land have been reforested and

improved timber management has been brought about on over 2 million acres of private lands throughout the valley.

The effects of the agriculture and forestry programs have been measured in several small watersheds by TVA. These measurements are an index to benefits that have resulted from the improvement programs.

In the 85,000-acre Chestuee Creek watershed in eastern Tennessee, improved watershed cover and land management resulted in reductions in sediment loads of 48 percent in a 10-year period without any reduction in water yield.

In an 88-acre research watershed in western Tennessee, which originally contained numerous deep gullies and severe sheet erosion, watershed improvement embracing tree planting, contour furrowing, diversion ditching, and check dams in the stream channels and gullies resulted in tremendous improvement. Hydrologic measurements throughout a 20-year period in this small area have shown that surface runoff volumes have decreased and ground-water discharges have increased. Peak discharges of moderate summer and winter floods have been reduced. Surface runoff volumes from individual storms before treatment were 1½ to 4 times those after treatment. The rate of sediment removal and measure of erosion activity have progressively decreased to less than 5 percent of the original amount.

Similar results have been measured on the White Hollow watershed, a 1,715-acre area near Norris Reservoir, where the originally cleared and generally eroded area has been improved under forest management and protection to give a continuously improving vegetal protective cover.

In the Parker Branch watershed in western North Carolina, a 1,000-acre area, watershed improvement has been carried out with the objective of maximizing income from the land and observing hydrologic effects on the watersheds. Results to date indicate that the two objectives are compatible.

The knowledge gained from watershed research projects is being specifically used wherever applicable in problems of the several hundred small watersheds within the valley. In many of these watersheds, improvement of ground cover and better watershed management offer the only feasible solutions to the water problems encountered. TVA recognizes the need for work in these watersheds in the interest of watershed improvement and in bettering the economic conditions of people residing on the lands. To this end, TVA is working with the valley States to develop State responsibility and leadership in improvement of small watersheds. TVA gives such technical assistance as may be requested in solving the watershed problems. In the long run, this approach should result in a virile State and local leadership with the capacity to solve problems met within small watersheds.

The effectiveness of these small watershed programs shows that greater income can be expected from the land, as well as improved watershed protection with decreased erosion and reduction in sediment in reservoirs—all important objectives in an integrated resource development program. Nevertheless, such programs do not result in significant reductions of major floods and, therefore, TVA has not attributed flood control benefits to the programs.

TVA Flood Control Reservoir System

MULTIPLE-PURPOSE APPROACH

The TVA Act of May 18, 1933, specifically authorized the construction of "* * * dams, and reservoirs, in the Tennessee River and its tributaries * * *" that will best serve to "* * * control destructive floodwaters in the Tennessee and Mississippi River drainage basins * * * *"

The TVA Act also directed a unified approach to resource development, and it carried some specific guidelines for development of the river. Navigation was to be provided by a 9-foot-draft channel extending from the mouth of the Tennessee River to Knoxville, Tenn. Destructive floods in the Tennessee River and Mississippi River Valleys were to be controlled. Power potential created by the construction of dams was to be fully developed. While these directions were clear, they left ample room for determination of the best overall solution.

One of the early major decisions in system planning was the choice of high dams on the main stem of the Tennessee River. The alternatives considered were a system of some 30 low dams for

navigation only or a series of 9 high dams (including 2 existing dams) that would provide the required navigation channel but also would create flood storage capacity and a power potential of 1,651,000 kilowatts. The choice of high dams increased the effectiveness of the entire system for flood regulation along the Tennessee River and also made possible substantial reductions of flood stages on the Ohio and Mississippi Rivers.

DESCRIPTION OF THE SYSTEM

In compliance with the congressional authorization and directive to construct dams and reservoirs to control floods, the TVA water control system in the Tennessee River Basin consists of 25 major dams and reservoirs, 9 on the main Tennessee River and 16 on tributaries. In addition, there are three small acquired projects and six belonging to the Aluminum Co. of America which are operated in accordance with instructions by TVA under agreement. Of the 9 main river projects, 8 have a storage reservation for flood control; and of the 16 tributary projects, 10 have a storage reservation for flood control. Thus, in the system there are 18 projects where capacity for storing of floodwater is assured. The locations of these projects are shown on figure 3, and drainage area and the volume of reservations for flood storage are given in the table on page 11.

Although there are seven projects where it has not been feasible to provide flood storage reservations, some of these will automatically have a beneficial regulating effect during most floods. Some of these reservoirs will be drawn down during the normally dry autumn for power generation and will be at low levels at the beginning of the flood season about the end of December. Subsequent filling may coincide with the occurrence of a flood, resulting in reduced flows. However, because in a prolonged wet period in January and February they might be filled or nearly filled by March, these reservoirs are not included as part of the dependable flood control system.

In the system, a total of at least 11,800,000 acre-feet of flood storage capacity is available on January 1 of each year. This reservation may be reduced as the season progresses to 10,400,000 acre-feet in mid-March. A total of nearly 2,500,000 acre-feet is held available for flood control operations during the summer months.

FLOOD CONTROL PLANNING

The natural division of the Tennessee River Basin into two approximately equal parts having different physical characteristics made the planning of the reservoir system two more or less independent problems. Moreover, the principal areas subject to damaging floods were located at the downstream end of each of these two parts. Flood control planning, therefore, focused on two key areas: (1) the flood-vulnerable midvalley area at Chattanooga, Tenn., and (2) the lower Ohio-Mississippi River region. The city of Chattanooga presented one of the most serious urban flooding problems in the country, and the flooding of extensive agricultural lands as well as cities on the lower Ohio and Mississippi Rivers was of equal or greater importance. Other local flood problems, such as at Asheville, Elizabethton, Kingsport, and Knoxville, also influenced the reservoir planning with respect to both the selection of reservoir sites and the capacity and operation of the reservoirs.

Chattanooga.—The most effective plan for fully adequate protection at Chattanooga against floods of "maximum probable" proportions was found to be a combination of upstream reservoir storage and local protective works. Consideration of feasible levee heights at Chattanooga and available upstream reservoir sites led to a plan for the provision of 4 million acre-feet of flood storage capacity distributed throughout the tributary streams of the upper valley. This amount of reservoir capacity was to be available in mid-March, with greater amounts required at the outset of the flood season late in December.

Major reservoir sites identified on the five principal tributaries above Chattanooga would control a combined drainage area of 13,420 square miles. Storage capacity of 4 million acre-feet, distributed uniformly with respect to drainage area, would be equivalent to about 5.6 inches over this area. As would be expected, however, uniform distribution to available reservoir sites was not feasible or desirable. The actual distribution took into account, in addition to the size of each drainage area, the average contributions to Chattanooga floods, the relative unit cost of storage at the several projects, and the physical site limitations. As a result, the flood storage provided in mid-March varies from 4.2 inches at Douglas on

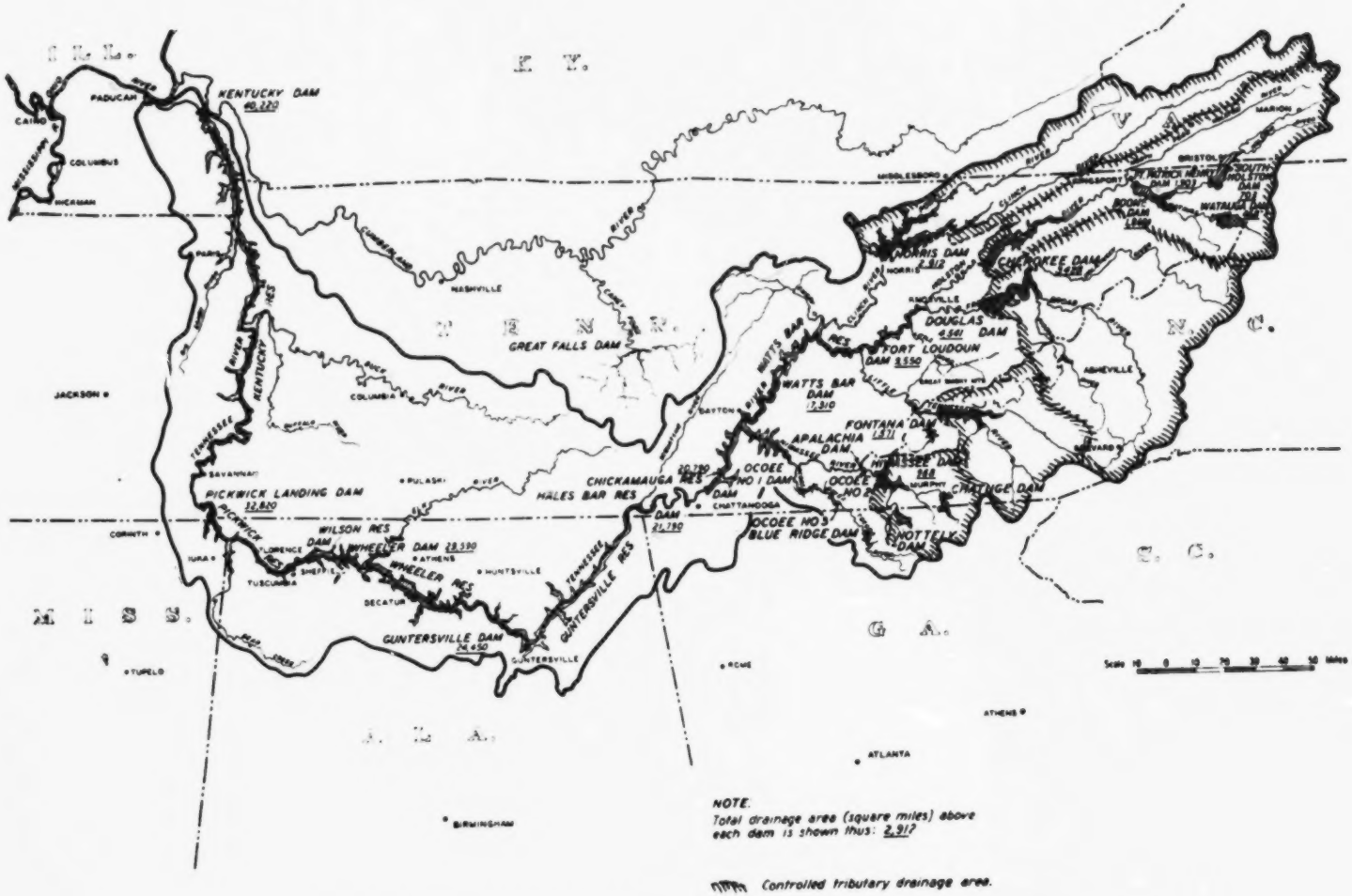


FIG. 3. TENNESSEE VALLEY FLOOD CONTROL RESERVOIRS

Storage reserved for flood control

Reservoir	Drainage area above dam		Controlled headwater maximum elevation	Jan. 1			Mar. 15			Summer level		
	Total square miles	Net [1] square miles		Seasonal elevation	Storage [2]		Seasonal elevation	Storage [2]		Seasonal elevation	Storage [2]	
					Acre-feet	Inches [3]		Acre-feet	Inches [3]		Acre-feet	Inches [3]
Tennessee River projects:												
Kentucky	40,200	7,380	[4] 375	354	4,010,800	10.19	354	4,010,800	10.19	359	1,044,200	2.66
Pickwick Landing	32,820	2,070	418	408	418,400	3.79	408	418,400	3.79	414	179,200	1.63
Wilson	30,750	1,160	507.88	504.5	53,000	.85	504.5	53,000	.85	507.5	6,000	.10
Wheeler	29,590	5,140	556.28	550	347,500	1.27	550	347,500	1.27	556	19,400	.07
Guntersville	24,450	3,660	595.44	593	162,900	.83	593	162,900	.83	595	31,200	.16
Chickamauga	20,790	2,512	685.44	675	329,400	2.46	675	329,400	2.46	682.5	108,500	.81
Watts Bar	17,310	3,277	745	735	377,600	2.16	735	377,600	2.16	741	163,500	.94
Fort Loudoun	9,550	1,581	815	807	109,300	1.30	807	109,300	1.30	813	30,000	.36
Total	.....	26,780	.....	.....	5,808,900	4.07	.....	5,808,900	4.07	.....	1,582,000	1.11
Tributary projects:												
Hiwassee	968	565	1,526.5	1,455	291,100	9.66	1,472	245,100	8.13	1,5[illegible]6	12,400	.41
Chatuge	189	189	1,928	1,910	105,400	10.46	1,916	75,100	7.45	1,92[illegible]	7,100	.71
Nottely	214	214	1,780	1,743	110,000	9.64	1,755	83,500	7.32	1,779	4,200	.37
Norris	2,912	2,912	1,034	978	1,635,000	10.53	990	1,377,000	8.87	1,020	520,000	3.35
Fontana	1,571	1,571	1,710	1,615	771,200	9.20	1,544	581,800	6.94	1,708	21,200	.25
Douglas	4,541	4,541	1,002	935	1,311,200	5.41	958	1,019,800	4.21	1,000	62,100	.26
Cherokee	3,428	1,588	1,075	1,020	1,145,900	13.52	1,042	807,200	9.52	1,073	61,400	.72
South Holston	703	703	1,742	1,702	286,300	7.64	1,713	218,200	5.82	1,729	105,800	2.83
Boone	1,840	669	1,385	1,358	93,000	2.61	1,374.6	41,400	1.16	1,385	0	0
Watauga	468	468	1,975	1,934	256,200	10.26	1,952	155,400	6.23	1,959	109,000	4.37
Total	.....	13,420	.....	.....	6,005,300	8.39	.....	4,604,500	6.43	.....	903,200	1.26
Grand total	40,200	.....	.....	.....	11,814,200	5.51	.....	10,413,400	4.86	.....	2,485,200	1.16
Total above Chattanooga	21,400	.....	.....	.....	6,821,600	5.98	.....	5,420,800	4.75	.....	1,205,200	1.06

[1] Net drainage area excludes those areas above upstream storage dams.
[2] Level pool storage between normal maximum elevation and seasonal elevation.
[3] Equivalent depth over net drainage area.
[4] Limited to elevation 365 for 6 months after June 1.

the French Broad River to 8.9 inches at Norris on the Clinch River.

Additional storage capacity was planned at main-river projects upstream from Chattanooga. At these projects, minimum reservoir levels were fixed by navigation requirements. Maximum levels were largely influenced by existing cultural development and the cost of reservoir adjustments. Within these controlling levels, only limited flood storage could be planned (about one-third of that in the tributary reservoir per square mile of drainage area) for the regulation of runoff from an otherwise uncontrolled drainage area of 7,980 square miles between tributary reservoir sites and Chattanooga.

Lower Ohio-Mississippi Valley.—The second key planning objective was to contribute flood relief to the lower Ohio-Mississippi Valley. Fulfillment of this objective was possible because of two factors: First, because the unregulated contribution of the Tennessee River to Mississippi River floods is nearly always a substantial amount and has been as great as 30 percent of the peak discharge at Cairo, Ill.; second, because the availability of the Kentucky project would provide 4 million acre-feet of usable storage control at a point only about 20 miles from the mouth of the Tennessee River. Due to this favorable location, regulation of Tennessee River discharges at Kentucky Dam is effective on the Ohio and Mississippi Rivers almost without diminution. Comparison of the volume in the crest of past Mississippi River floods with the volume of Tennessee River floods during a corresponding period of time, adjusted for water travel time, showed that reductions of from 2 to 4 feet can be accomplished in major floods.

Between Kentucky Reservoir and Chattanooga, five main-river projects create the navigable channel, develop the power potential, and provide limited amounts of flood-regulating capacity. Their flood control function is to supplement the upstream regulation in the protection of communities and land along the lower Tennessee River by short-term regulation during flood crests. They also supplement Kentucky Reservoir in reducing Ohio-Mississpppi River flood crests.

OPERATION PLAN

Chattanooga.—The operation of the reservoir system for flood control at Chattanooga follows the pattern of (1) storage in tributary reservoirs, (2) rapid discharge of early flows through the mainstream reservoirs, (3) storage in mainstream reservoirs during the period of crest flow, and (4) postflood drawdown of mainstream and tributary reservoirs to flood control levels.

At the tributary reservoirs, excess flows are stored throughout the period of regulation for Chattanooga. If these reservoirs are below flood reservation levels, discharges are limited to turbine capacity or less. As storage space above these levels is filled, discharges may be increased gradually to insure retaining control in case a flood of extreme proportions should occur. Figure 4, the multiple-purpose operating guide curve for Douglas Reservoir, is typical of the operation of tributary reservoirs. The actual reservoir elevations during the 1957 flood season are also shown.

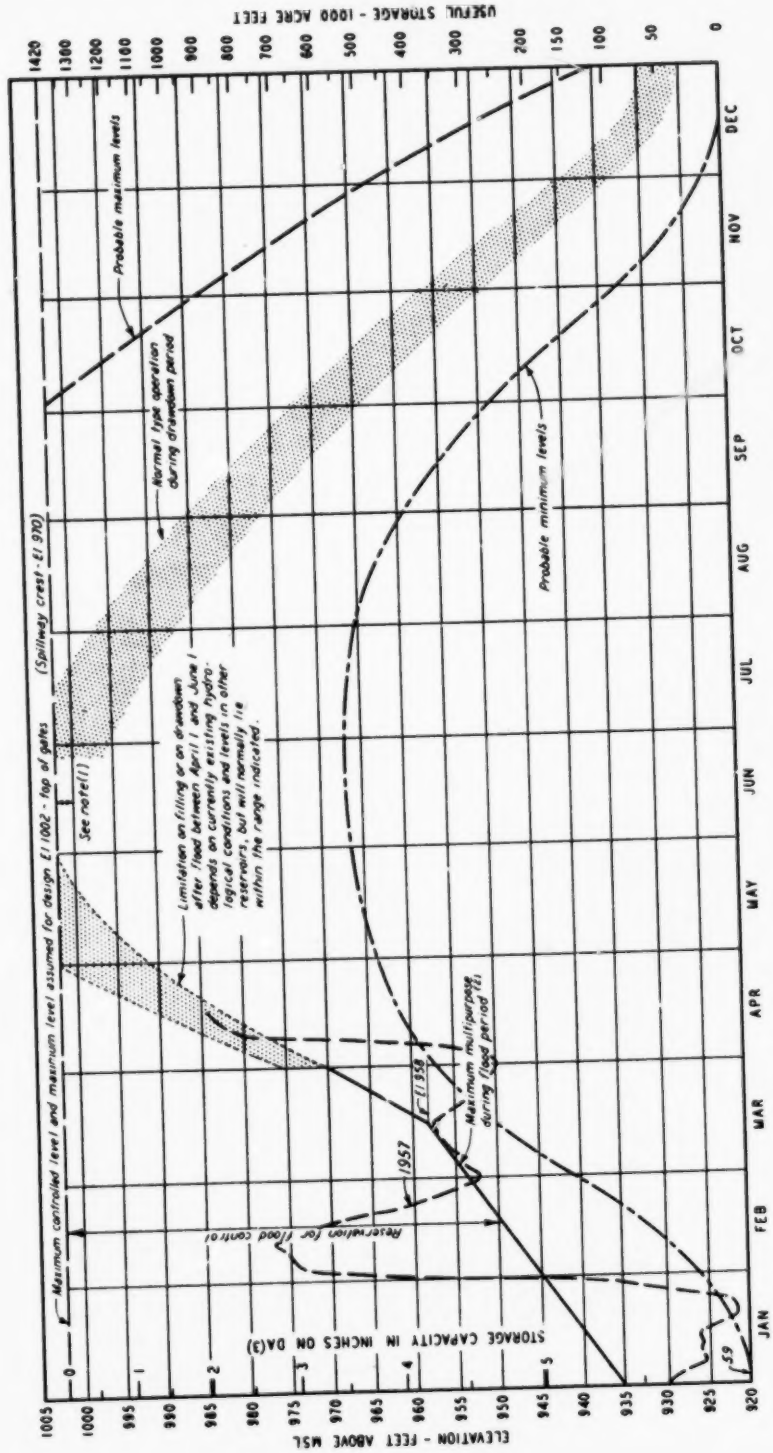
At mainstream reservoirs, the early buildup of flows below the tributary reservoirs is passed rapidly downstream, reserving storage space for regulation of the crest flow. If practical, advance drawdown is made at the dams to provide additional storage space. As the flood develops and Chattanooga reaches near flood stage, regulation is begun. Releases at Chickamauga Dam are adjusted to reduce the Chattanooga crest stage as much as prudent operation indicates. As at the tributary reservoirs, the release must be controlled, depending on the magnitude of the flood, so as to reserve some margin of reservoir volume in case higher flows should develop. Figure 5, the multiple-purpose operating guide curve for Chickamauga Reservoir, is typical of the operation of the main-river reservoirs. The actual elevations during the 1957 flood season are also shown.

As soon as the crest stage is passed, drawdown of the mainstream reservoirs is started to prepare the system in case a second flood should occur. Outflow rates are adjusted to maintain full channel conditions downstream and thus to accelerate the withdrawal. Releases at tributary dams are also increased to the highest feasible rates in order to further relieve the system of floodwaters and restore the flood-regulating capacity of the system as quickly as possible.

Kentucky Reservoir.—The operation of Kentucky Reservoir for the lower Ohio-Mississippi Rivers follows a different pattern. The objective is not a flat, regulated outflow at Kentucky Dam, but an outflow which combined with Ohio-Mississippi River flows will produce the desired flat, regulated crest on the Ohio River at the Cairo gage. Flood crests on the lower Tennessee are not usually coincident with those on the Ohio-Mississippi. High discharge rates from Kentucky Reservoir are usually possible early in the flood period, and the reservoir at the dam may be drawn below the normal level. Gradual reductions in releases are then made as the crest approaches, and releases are regulated as needed to obtain the maximum practical crest reduction. Postflood emptying of the reservoir is then started at rates dependent upon the flows and stages on the Ohio-Mississippi Rivers.

Section 7 of the Flood Control Act of December 22, 1944, provides that "* * * in case of danger from floods on the lower Ohio and Mississippi Rivers the Tennessee Valley Authority is directed to regulate the release of water from the Tennessee River into the Ohio River in accordance with such instructions as may be issued by the War Department (Department of Defense)." This statute serves the purpose of integrating flood control operations of the Kentucky Reservoir with the flows on the Ohio and Mississippi Rivers under the control of the Corps of Engineers. The division engineer, Ohio River division, has been designated formally by the Secretary of Defense as the representative of that department responsible for issuance of instructions to TVA for regulating releases from the Tennessee River when danger from floods exists on the lower Ohio and Mississippi Rivers.

Since the above statute was enacted, periodic conferences have been held between the Corps of Engineers and TVA engineers to perfect arrangements by which the exchanges of flood data are made and to clarify matters pertaining to the release of water from the Tennessee River in time of flood. The results of these conferences were formalized by a joint manual which was issued in 1957.



NOTES:
(1) Reservoir would normally be drawn down 2 feet or more through turbines to provide storage space for control of runoff from freshets.
(2) To be exceeded only during flood control operations.
(3) Based upon drainage area, 4341 square miles.

FIG. 4. MULTIPLE-PURPOSE OPERATING GUIDE CURVE - DOUGLAS RESERVOIR

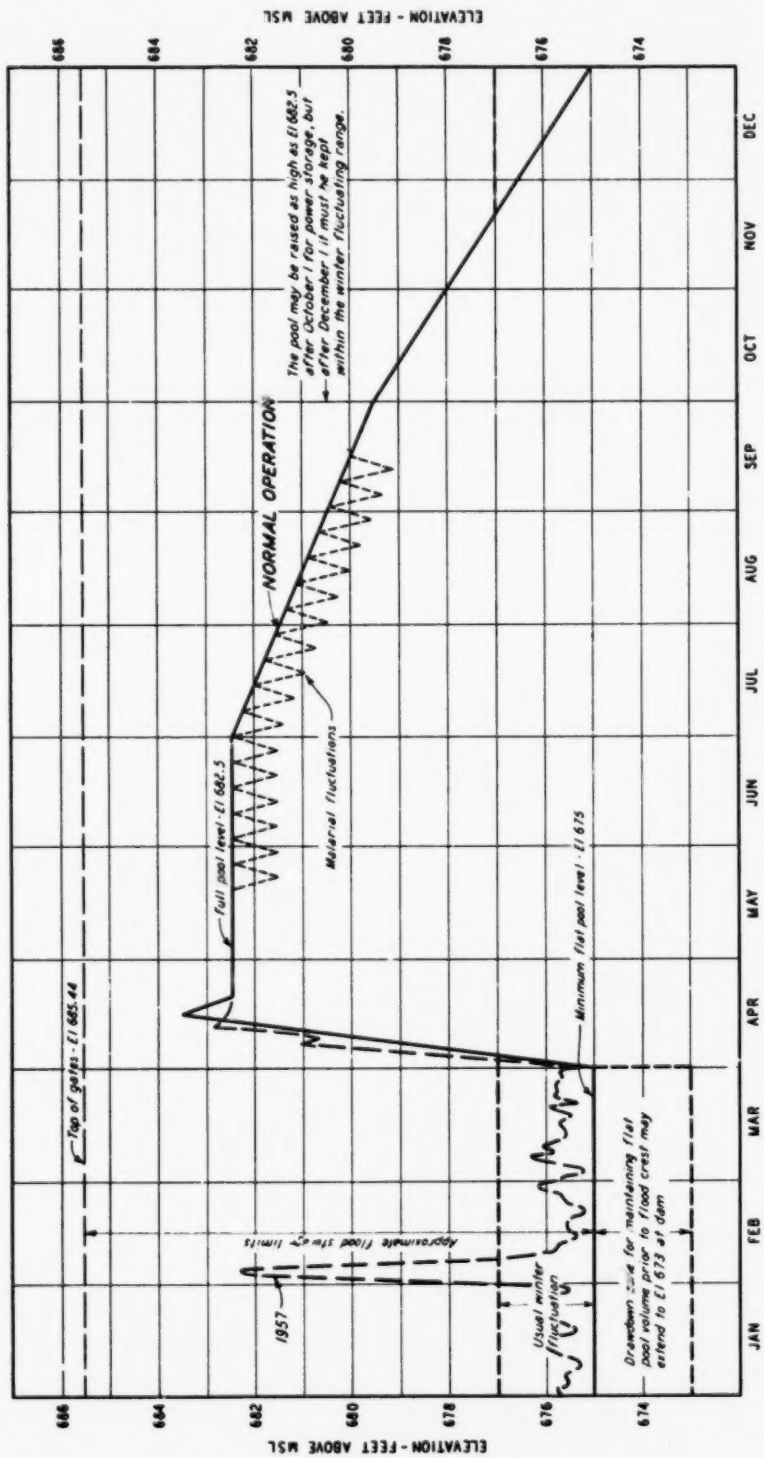


FIG. 5. MULTIPLE-PURPOSE OPERATING GUIDE CURVE - CHICKAMAUGA RESERVOIR

ALLOCATION OF INVESTMENT TO FLOOD CONTROL

The total investment in the multiple-use river development projects of the TVA system at June 30, 1958, was $744 million. The underlying allocation method adopted by TVA in 1938 and used in subsequent allocations is known as the alternative justifiable expenditure method. This approach is essentially the same as the so-called separable cost-remaining benefit method adopted in recent years by some other Federal agencies.

Alternative costs are based on estimates of the most economical system of single-purpose structures separately for navigation, flood control, and power which would furnish substantially the same quantity and quality of service for the single purpose as that provided by the multiple-purpose system. As most of the alternative projects were assumed to be built at sites of actual multiple-purpose projects, the estimates generally reflect actual knowledge of construction conditions. Estimates for single-purpose projects were based on construction cost levels experienced at the time of construction of the corresponding multiple-purpose project.

The alternative single-use system for flood control includes reservoirs on the main river and major tributaries to provide flood control storage equal in amount and effectiveness to that provided by the multiple-purpose system as built. The average cost per acre-foot of storage in this alternative single-use flood control system was determined to be $22. This unit cost was then applied to the actual amount of storage capacity available in the multiple-purpose system to determine an alternative justifiable expenditure for flood control of $260,458,000, which was about 31 percent of the total alternative justifiable expenditures, less direct investments, for all three purposes.

The application of 31 percent to the total common cost for all three purposes results in the allocation of $127,961,554 to flood control purpose. The direct investment of flood control works in service was $56,120,966 as of June 30, 1958, making the total system investment for flood control equal to $184,082,520.

ANNUAL CHARGES FOR FLOOD CONTROL

The investment of about $184,083,000 forms the basis of calculating the annual fixed charges of interest and amortization. The average interest rate paid by the U. S. Treasury on long-term bonds over the period of construction of TVA's multiple-purpose projects was about 2¼ percent, so this rate was adopted. It seems only proper in setting up the justification of such projects that an allowance for amortization be made which would equal the depreciable cost of the project in a reasonable period of time. For the purposes of this report, a period of 50 years has been set in which to amortize the depreciable items. It was assumed that the cost of lands and land rights, clearing, and relocation were nondepreciable. The nondepreciable items at June 30, 1958, totaled $79,903,000. Since these costs are not to be amortized, interest charges should be in perpetuity.

The annual operating and maintenance costs of multiple-purpose projects are based on 7 fiscal years (1952 to 1958) actual experience. These costs are apportioned among navigation, flood control, and power, either on the basis of their relationship to the primary programs or in the same percentage as used in the allocation of capital costs.

The annual fixed charges against flood control are $5,671,000, and the average annual operation and maintenance charges are $1,101,000. The total average annual charges on this basis to flood control are $6,772,000 on a total investment of $184,083,000.

Average annual charges against flood control

Fixed charges:		
Interest only: $79,903,000×0.025		$1,998,000
Interest and amortization: $104,180,000 ×0.0352581 [1]		3,673,000
Total average annual fixed charges		5,671,000
Operation and maintenance:		
Operation	$972,000	
Maintenance	59,000	
Administration and general	70,000	
		1,101,000
Total annual charges		6,772,000

[1] Annual payment required to amortize $1 and interest at 2¼ percent in 50 years.

AVERAGE ANNUAL BENEFITS FROM FLOOD CONTROL

Average annual flood control benefits attributable to the TVA reservoir system were estimated from the damages preventable in the period of flood record of about 100 years and from the in-

creased land values by virtue of more complete protection of Mississippi River leveed areas.

Areas which receive protection from the reservoirs may be either fully or partially protected, as follows.

Areas given substantial year-round protection.—The extent of lands flooded will be only moderately greater for the maximum probable flood than for the maximum flood of record. The greatest flood of record, therefore, was adopted as the upper limit to which benefits would be determined. The profile of this flood as reduced by reservoir regulation constitutes the lower limit to which full protection will extend. The difference between the two will encompass the area given substantially complete protection. The area so defined is estimated to be 110,800 acres.

Partially protected land.—Land lying between the profile of the maximum flood of record, as reduced by upstream reservoirs, and a flat pool from the maximum allowable summer level at the dam receives only partial protection. A considerable portion of this land will be more productive than formerly, due to the reduction in frequency and depth of flooding. The area in this category on which benefits can be estimated is 152,900 acres. Most of this land and that described in the preceding paragraph lies in the upper reaches of the main Tennessee River reservoirs and on the tributaries downstream from the flood control reservoirs.

Benefits to cities.—Located in both the areas defined in the two foregoing paragraphs are a number of cities receiving benefits resulting from the reduction of flood crests. These benefits, based on average annual damage preventable by the TVA reservoir system, have been determined to be $5,556,000 (1953 status). They are primary tangible benefits, directly related to the affected property or to the avoidance of costs connected with the flood.

Estimates of preventable damages at Chattanooga were based on a detailed survey of the city in 1938 from which a stage-damage relationship was developed. This relationship has been brought up to date for increased values and new developments by supplemental surveys in 1948 and 1953. Similar but less detailed estimates were made for other cities.

At Chattanooga, the reduction in flood peaks by the reservoir system makes feasible the construction of levees which would afford additional protection and benefits which have not been included.

Benefits to agricultural land.—Also included in both areas defined above are agricultural lands, some of which are completely protected in a flood equal to the maximum crop-season flood, and some of which have the frequency or depth of flooding reduced. The amount of this cropland is estimated to be approximately 100,000 acres, and the agricultural damages preventable by the reservoir system have been determined to be $363,000 per year.

Benefits to the lower Ohio and Mississippi Rivers.—One of the principal purposes of TVA as stated in the statute under which it was created is "to control the destructive floodwaters in the Tennessee River and Mississippi River Basins."

Primary tangible benefits along the Mississippi River resulting from TVA reservoir operation include preventable flood damages to the 4 million acres between Cairo and the mouth of the Red River lying in the unprotected areas of western Kentucky and Tennessee, western Mississippi and eastern Louisiana, and in the backwater areas of the St. Francis, White-Arkansas, and Yazoo Rivers. The reduction in area of the average annual overflow amounts to about 386,000 acres, of which 88,000 acres were cultivated at the time of the study. The preventable damage includes damage to agricultural crops, railroads and highways, seepage damage, and savings in levee maintenance. Damages to agricultural crops vary with the date of occurrence of the flood. On the basis of monetary values as of 1953, preventable damages for the period of flood record of about 100 years on the 4 million acres have been estimated to be $2,869,000 per year. Damages in floodway lands in the Birds Point-New Madrid and Eudora Floodways are not included in these estimates. Moreover, benefits to timberlands resulting from flood reduction have not been considered, such as the possible conversion of timberlands to cultivated lands.

The greater security resulting from upstream reservoir regulation would be reflected in an increased value of the land, and the additional security obtained is estimated to bring an increase of $25 per acre to the 6 million acres now protected, or a total increase of $150 million. To reduce this lump-sum increase to an average annual benefit

so as to make it comparable with other average annual benefits, it is multiplied by 3 percent, giving an average annual benefit of $4,500,000. The selection of the multiplier of 3 percent is believed to be conservatively low if it is considered as a return on a farm investment or a business enterprise.

Summary of annual flood control benefits.—A summary of the flood control benefits in the various areas due to the flood control system in the Tennessee River Basin is as follows:

Summary of average annual flood control benefits

Average annual preventable damage:	
Tennessee River Basin:	
Chattanooga	$5,252,000
Knoxville	65,000
Lenoir City	26,000
Loudon	18,000
Dayton	22,000
Clinton	26,000
Kingsport	45,000
Elizabethton	92,000
Other	10,000
Agricultural lands	363,000
Total Tennessee River Basin	5,919,000
Lower Ohio and Mississippi Basins	2,869,000
Total average annual preventable damage	8,788,000
Increase in land value: Lower Ohio and Mississippi Basins	4,500,000
Total average annual flood control benefits	13,288,000

OTHER BENEFITS FROM RESERVOIR SYSTEM

Incidental benefits to other water use programs are achieved as a result of storing floodwater during the operation of the reservoir system for its primary purposes—navigation, flood control, and power. Municipal and industrial water supplies have been greatly enhanced in quantity and quality, and suitable sites with adequate supplies of water are made available for large modern steam generating plants. For example, the low temperature of water released from Norris Dam substantially increases the operating efficiency of TVA's Kingston Steam Plant. The release of previously stored floodwater during periods of low flows also contributes to the improvement of navigation on the Mississippi River and to the prevention of salt water intrusion into the Mississippi from the Gulf of Mexico.

BENEFIT-COST RATIO

The average annual flood control benefits, as measured only by the average annual preventable damage in the Tennessee River Basin and on the lower Ohio and Mississippi Rivers from the 19 multiple-purpose projects in the Tennessee River Basin, are $8,788,000. This results in a benefit-cost ratio of 1.30:1. If the increase in value of lands that will be completely protected by a 2-foot lowering of the maximum flood against the Mississippi levee is taken into account, this ratio becomes 1.96:1.

ACCOMPLISHMENTS

Preceding sections of the report describe the nature and extent of the protection that has been afforded by the reservoir system. This section summarizes the accomplishments since completion of the system and compares accumulated benefits with total costs.

There are now 770 miles of river below the multiple-purpose dams where the agricultural lands on the bottoms on both sides of the stream have the frequency of flooding reduced greatly.

The flood of February 1957 at Chattanooga would have reached a stage of 54 feet, the second highest of record, under natural conditions, but was actually reduced nearly 22 feet to the point where only minor damage occurred. Substantial but smaller reductions have been achieved at Chattanooga in 33 floods since 1936. Damages averted in these floods, from the stage-damage relationship pertaining at the time, now total $120,213,000.

Along the lower Ohio and Mississippi Rivers, substantial reductions in flood damages have been achieved in 12 of the 15 years since Kentucky Reservoir was completed in 1945. At Cairo, the great flood of January 1950 was reduced 1.9 feet. The flood of May 1958 was reduced 3.1 feet, and although it was a smaller flood than that of 1950, it was more significant in prevented damages because of the date of its occurrence. In other floods the stage at Cairo can be reduced up to 4 feet, depending on the contribution of the Tennessee River to the peak on the Ohio River. Damages averted since 1945 on the land not

protected by the Mississippi River levee system now total $20,151,000.

The total damages averted to 1959 by virtue of flood reductions in actual floods experienced since 1936 total $140,364,000, or about 75 percent of the total capital investment of $184,083,000 allocated to flood control. This total includes only the damages averted at Chattanooga and in the lower Ohio-Mississippi River Valleys, since it has not been practicable to accumulate damages averted at all other locations in the Tennessee River Basin.

The benefits to the Ohio-Mississippi region of increased land value, by virtue of greater security against floods, may be considered as accruing in total immediately upon completion of the protective works instead of on an annual basis as in a previous paragraph. This benefit from the TVA system, estimated at $150 million plus the incomplete total of $140,364,000 of damages averted, makes the total accumulated benefits to date in excess of $290,364,000.

Flood control costs to date, including the capital investment of $184,083,000, an allowance for interest of $67 million on this investment, together with operation and maintenance expenditures of $19 million, total $270,083,000. Comparison with accumulated benefits thus shows that benefits over a period of only 23 years are more than sufficient to amortize the entire flood control investment, plus all accumulated annual expenditures and an allowance for interest, and the system will continue to supply these benefits for many years to come.

Controlling the Use and Occupancy of Flood Plains

REMAINING FLOOD PROBLEMS

The TVA system of multiple-purpose dams and reservoirs is the usual approach to flood damage prevention. It affords complete protection in some areas and materially reduces the depth and frequency of flooding in others. Despite this efficient and fairly complete system, there remain many communities and areas having flood problems but not flood damage prevention measures. For most of these remaining problem areas, no economically feasible plan of protection can be devised. Within the valley it is estimated that there are 20 or more communities for which protective works are not feasible for each community where such a solution may be economically justified.

NEW APPROACH NEEDED

There is evidence that the flood damage potential of the Tennessee Valley is increasing. The tremendous urban growth now taking place is pushing new developments into the inviting, open, level flood plain areas. Obviously, a new and different approach is essential to stem the growing flood damage potential.

What has been happening at Chattanooga, Tenn., illustrates this point. In the past 20 years, there has been a net increase of residential, commercial, industrial, public, and other types of structures in areas subject to floods. The TVA reservoir system can reduce a flood of the same magnitude as the maximum of record (1867) by about 18 feet, and it can reduce other great floods by substantial amounts. However, larger floods, which even when regulated will produce stages as high as the record flood, are still possible, and levees are needed to supplement the reservoir system in order to give complete protection. Nevertheless, construction of homes and commercial buildings has been allowed to proceed in the potential flood damage areas, and damages during great floods now would amount to many millions of dollars in spite of protection afforded by the reservoir system. Only recently the city began to meet the problem by restricting new development in the lower sections of the flood plain.

The increase in the flood damage potential of the valley is not confined to areas along the Tennessee River and its major tributaries. Cities throughout the valley are growing. Many of these are upstream from the reservoirs, and much of the new growth is occurring in flood hazard areas. Examples are Kingsport, Gatlinburg, Bristol, and Dayton, Tenn. As growth continues, the flood damage potential becomes greater.

The movement of new development into flood plain areas in the Tennessee Valley is not unique. Along the coasts and rivers of the United States, it is increasing to such an extent that the flood damage potential of the entire Nation is growing despite large Federal expenditures for flood control.

TVA COOPERATIVE PROGRAM

In 1953, TVA began a cooperative program with the valley States and local communities in which flood damage prevention is considered as a problem of adjusting the use of the land to the conditions existing in areas subject to flood. Viewed in this manner, the prevention of local flood damages becomes an essential part of community planning and development. It means giving adequate consideration not only to levees, dams, and other protective structures, but also to the use of zoning and subdivision regulations, to land acquisition for parks and open spaces, to planning of streets and utilities, and to construction standards for buildings which must be located in flood hazard areas. It requires cooperative effort on the part of Federal, State, and local government groups, but places in local hands the responsibility for solving the problem.

The various cities and communities are advised that TVA will assist them, at their request, in making a study of their particular flood problems. When a community requests information on its flood situation, TVA draws on the large amount of flood data which it has already assembled in planning and operating its system of reservoirs. It supplements these data wherever necessary and prepares a report summarizing the flood hazard for the particular locality. The completed report is furnished to the community and the State planning agency. State planning technicians then assist the local planning commission in using the data. The report provides information, including maps showing areas flooded, stream cross sections, and profiles of historical floods and larger floods that may be reasonably expected. The report does not recommend plans for solving the flood problem but provides a basis for further study and planning on the part of the community itself.

In the past, local governments have usually asked Federal agencies for reports directed toward the single purpose of justifying protective works. Such reports usually do not give a community sufficiently detailed data to appraise its overall flood problem. On the other hand, the flood data in the TVA reports are presented in a form useful to government agencies, industries, financial institutions, local officials, and private individuals interested in adjusting their activities to the flood conditions.

There are more than 100 communities in the Tennessee Valley having local flood problems. More than 70 of these have requested flood reports. By July 1959, reports had been prepared for 52 communities, about 10 being completed each year.

USE OF FLOOD REPORTS

On the basis of the flood information contained in TVA's reports, a planning study is prepared by the local planning agency with the help of the State. The solution to the flood problem may involve flood protection works or flood plain regulations, or a combination of the two. However, in most instances, the planning studies lead to a proposal for establishment of a floodway in which structures that would block or unduly interfere with flood flows would be prohibited. Permissible uses of the floodway might include parking lots, outdoor theaters, and similar facilities not subject to severe flood damage. Buildings along the fringes of the floodway would have floor levels at or above the flood stage for which the zoning was adopted.

Twenty-one communities have completed or initiated planning studies, and nine communities have officially adopted some type of flood plain regulations. Through the action of local officials, subdivisions, schools, streets, and other improvements at numerous communities have been shifted to locations on higher ground reasonably safe from floods, thus reducing the possibility of future damages.

The flood reports are also used by State highway departments in planning new highways and bridges, by State and private industrial development agencies in identifying flood-free plant sites, and by such Federal agencies as Veterans' Administration and Federal Housing Administration in guaranteeing or insuring home loans, and by Urban Renewal Administration and Public Housing Administration in planning and financing public projects. TVA also exchanges information and coordinates its activities on local flood studies with the Corps of Engineers.

Significant reduction in flood damages through these means is necessarily a slow process. How-

ever, when local communities understand the problem, they can accomplish a great deal through a program of land use controls for developments in low-lying areas. The acceptance that local governments have accorded the concept of land use regulation in the Tennessee Valley indicates it would have successful application in other regions.

Thus, TVA has found that a comprehensive plan involving Federal, State, and local government cooperation can be put into effect which will control the growth of the flood damage potential. The plan embraces a broad approach to flood damage abatement which includes preventive as well as corrective measures and places greater responsibility on State and local governments for solving local flood problems.

Suggestions for Future Federal Activity

The following suggestions, based on TVA's experience, might be helpful in the solution of flood problems in the Nation as a whole and are submitted for consideration by the committee.

1. Where feasible, continue planning and construction by the Federal Government of engineering flood control works, especially those on large watersheds involving purposes of nationwide or major region significance.

2. Expand the flood-forecasting services of appropriate Federal agencies, especially to areas for which flood control structures are not feasible.

3. Coordinate activities of appropriate Federal agencies with a view toward attaining a more uniform basis for computing flood control project design floods and flood control benefit estimates. The policy should not be static but should be kept up to date by taking into account additional data and improvements in flood hydrology and economic techniques.

4. A national flood damage prevention policy should be developed. The objectives of the policy should be (*a*) to prevent the unnecessary spread of buildings and other improvements to flood hazard areas, combined with continued efforts to alleviate damages in those flood hazard areas which have already been developed, and (*b*) to encourage appropriate State and local bodies to assume the responsibility for initiating and developing plans and programs for local flood damage abatement through construction of protective works and establishment of land use controls as necessary. The policy should also provide a basis for technical and financial assistance by Federal agencies.

5. If protective works are economically justified as a part of the local program for flood damage abatement, the Federal financial contribution to such projects should be contingent upon the requirements that the city or State initiate and prepare engineering plans of the proposed works and that the plans be submitted to an appropriate Federal agency for review and approval.

6. As a prerequisite for the contribution of Federal funds to local flood protective works, State and local governments should be required to adopt and administer flood plain zoning and other such controls as are needed to prevent the unnecessary spread of buildings and other improvements in areas subject to flood damage.

7. Provision should be made to insure that all Federal agencies having responsibility related to site selection or financing of physical structures observe local flood plain zoning and other standards in carrying out their responsibilities, and that the Federal agencies, in cities without land use controls but subject to flood damage, require establishment of such controls before Federal programs are approved and put into execution.

8. An expanded and systematic program of collecting and analyzing basic flood information by existing Federal agencies should be authorized which will meet the needs of States, local communities, industries, and others in planning their growth and development to prevent local flood damages. Appropriate Federal agencies should be authorized, where such authorization is necessary, to prepare upon request local flood studies which would describe and analyze the local flood situation.

9. Provision should be made to direct a portion of Federal, State, and local funds that are appropriated for flood control measures into the field of research on a continuing basis. For example, research is needed in rainfall measurement techniques and systems, in streamflow measurement and analysis, in the evaluation of floods, in flood-warning methods, in the use of radar for weather forecasts, in weather modification, in the economics of flood prevention measures, and in evaporation suppression. Research by appropriate agencies, conducted with and through the Nation's qualified universities and technical schools where possible, will assure progress and will strengthen university programs.

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